Interactive Solutions Group, Inc.

Windows NT 4.0 Server
Apple Workgroup Server 9650/350

Technology Comparison

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by
Grant K. Holcomb
President
Interactive Solutions Group, Inc.
P. O. Box 470908 Charlotte, NC 28247
6401 Carmel Road Suite 205 Charlotte, NC 28226
(704)542-1162
Marine@ISGreat.com

I. Introduction

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This document is a collection of facts regarding the differences between a typical Windows NT 4.0 server and an Apple Computer Workgroup Server 9650/350. This information should support a more educated selection process by any decision maker.

Interactive Solutions Group, Inc. (ISG) has produced this document at the request of a customer. Feel free to distribute. Enough information is provided to determine the best platform in the following categories:

- **Initial Purchase Price**
- **Level of Integration**
- **Expandability**
- **Performance**
- **Productivity**
- **Efficiency**
- **Reliability**
- **Life Cycle Cost**
- **Disaster Recovery**
- **Longevity**
- **Flexibility**

Windows NT 4.0 Server

or

Apple Workgroup Server 9650/350

To the greatest extent possible objective technical information from the respective manufacturer is presented. However, even this type of information can be misleading if not presented in the right context or with some understanding of how the figures were derived. Even the author is skeptical regarding some figures. However, with the addition of a reasonable tolerance of error, if one value is still significantly greater than another the advantage for the end user should be clear. Subjective observations based on experience are so noted.

Mac OS

This information is valuable for anyone seeking a reliable file server, print server, or database server for a small to medium work group (10 to 250 users). Particularly if you are seeking to reduce support labor costs while increasing productivity.

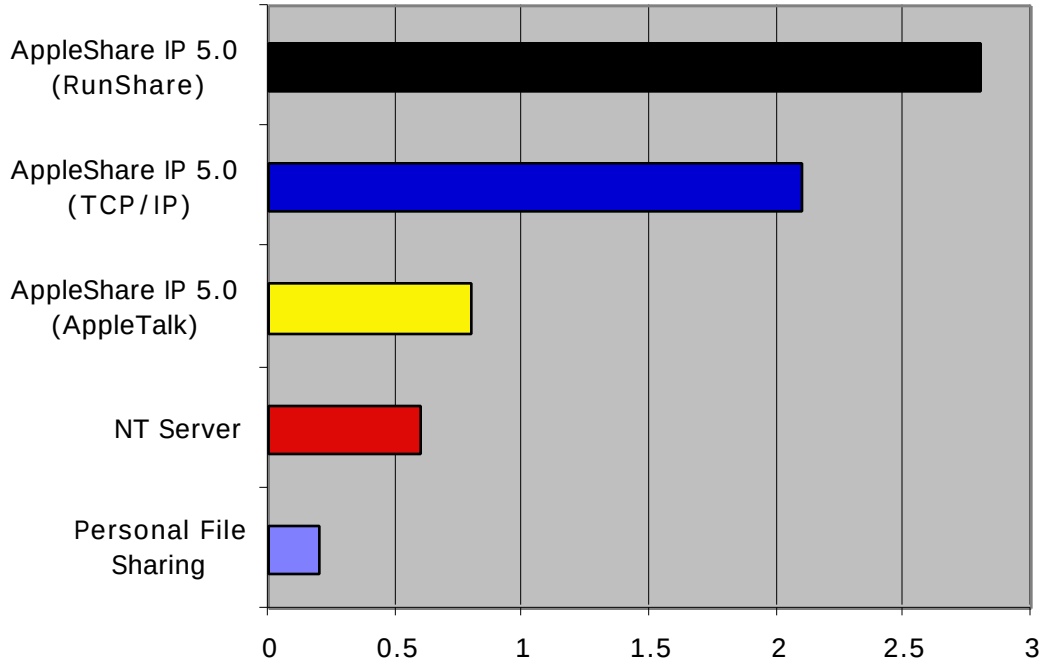
MOTOROLA

II. Performance Comparison

Out of respect for the busy executive the following performance comparisons are presented first. This page and the next page summarize the real world performance differences between the two systems. The rest of this document provides the necessary engineering details an IS professional will require.

File Server Relative Performance Comparison

(10 MByte File Transfers)



The above data was derived from tests done over a 100 Base-T Ethernet network. The client used was a 200 MHz Power Mac 8500. The NT server was a Compaq Proliant 1500 with a single 200 MHz Pentium processor. The Apple Computer server running AppleShare IP 5.0 was a Workgroup Server 9650/233 (233 MHz version of the Apple Workgroup Server). The data presented in the rest of this document lets the reader judge for themselves the impact of the new 350 MHz processor on the Workgroup Server's performance in comparison to a Windows NT 4.0 server using the faster Pentium Pro and Pentium II processors. It is easy to refute any data as unfair and biased. There are so many factors that must be considered. However, in the remaining sections it is easy to analyze the real limitations to data flow like processor performance, cache size, bus performance, and the impact of the respective operating systems. It is also easy to reproduce this test on your own.

The above data should leave you with many questions. For example, what happens to performance if I have 100 users on the Ethernet network? What happens if we add database server software to the mix? What happens if we add print server software to the mix? What happens if we add email server software to the mix? An understanding of how the respective architectures move data is required, thus the reason for the detail in the remaining sections of this white paper.

As part of this effort, the author sought a reputable way to present the real differences between the two platforms. Preferably a way to surface the impact on performance of the relationships between operating system, processor, cache, bus technology, and memory. It is a very complicated balance of cost, performance, and profitability that every manufacturer battles. All an end user cares about is the real return on invest from a server purchase.

Think of yourself as a single character of data and imagine what obstacles are in your way to move from a server to a client. This is in fact the bottom line issue - data throughput. Everything else is marketing fluff. You must travel from the processor, through the memory cache structure, through various buses and out onto a transport medium within a data packet. Upon arrival at your destination you do it all again in reverse until you become part of something useful - like productive work. There is an example on the Internet that surfaces the real world performance capabilities of various platforms. At your convenience go to the following URL on the Internet:

http://www.alde.com/rc5.html

and more specifically the following two URLs:

http://www.alde.com/x86speed.html and http://www.alde.com/ppcspeed.html

In summary, the RC5 project is designed to crack a security code. This code is astronomically large (2 to the 56th power in fact). A very large number of client applications have been written supporting most computer platforms and operating systems. This was not done to compare performance, but to have as many computers as possible attempting to find the exact code that cracks the security key. Each computer must generate a code, create and send a data packet containing the code, determine if the code cracks the security key by monitoring returned data packets, then repeat the cycle - as quickly as possible. This is a real test of performance and represents the fundamental data transport process used in file servers, print serves, database servers, and email servers. The following data represents the performance of the respective systems. Note that the values represent the number of security key codes processed per second:

Windows NT 4.0 and 200 MHz Pentium	**233,666**
Windows NT 4.0 and 200 MHz Pentium Pro	**487,537**
Windows NT 4.0 and 233 MHz Pentium Pro	**546,855**
Windows NT 4.0 and 233 MHz Pentium II	**548,365**
Windows NT 4.0 and 266 MHz Pentium II	**704,925**
Windows NT 4.0 and 300 MHz Pentium II	**715,732**
Mac OS 8, Power Mac 9600, and 300 MHz PowerPC 604e	**812,000**
Mac OS 8, Power Mac 9600, and 350 MHz PowerPC 604e	**1,012,000**

Competition makes our country great - the IBM and Motorola PowerPC processor is at the beginning of its life cycle with 400 MHz to 1 GHz solutions planned for the future.

III. Performance Issues

The following defines the elements of the two hardware achitectures that directly influence performance. The respective operating systems have a direct impact on overall performance, but this falls under a more subjective discussion in a later section. These terms and definitions are important to understand the next section which presents a head to head comparison of an actual Windows NT 4.0 server and the Workgroup Server 9650/350.

A.) RISC versus CISC - The PowerPC is a Reduced Instruction Set Computer (RISC) and the Pentium is a Complex Instruction Set Computer (CISC). The RISC processor has to execute more commands than a CISC processor to accomplish the same tasks. However, the PowerPC can execute 4 instructions per clock cycle. The Pentium's instructions execute at various clock cycles. The real impact on performance is that the PowerPC has millions of less transistors and much less complexity. The smaller die size means higher yields, lower cost, less power consumption, and much faster clock cycles. The PowerPC is at the beginning of its life cycle. The Pentium is rapidly reaching its complexity and speed limits. The Pentium has fewer registers and smaller on board caches because of these limitations. The next few issues summarize the impact of those limitations.

B.) Registers - A register is a memory storage space internal to the processor in which the respective processor stores intermediate and final values. Both processors (Pentium and PowerPC) have integer and floating point data storage registers. The values stored here are moved across the respective data buses to the other elements defined below. The PowerPC has twice as many registers as the Pentium allowing it greater performance for complicated algorithms. The performance increase is due to the ability to increment or change a register's value without using clock cycles to change values stored in the various cache locations or main memory.

C.) Level 1 Cache (L1 Cache) - Cache is high speed memory that the respective processors use to grab data and instructions. Both processors have caches built on the processor's die giving them access at the full speed of the processor's clock. This is called Level 1 Cache (L1 Cache). When either processor needs data or instructions to execute, if it is in the respective L1 cache, the performance of the operation is higher. The PowerPC has twice the amount of data and instruction L1 Cache as the Pentium II does.

D.) Level 2 Cache (L2 Cache) - This type of cache is also high speed memory, but resides outside the processors die. This means that precious clock cycles must be consumed to grab data and instructions stored there. However, this is preferable to grabbing data and instructions from the much slower main memory all computers have. Not all applications really need a large cache. However, supporting lots of simultaneous server clients is a good example of where it is needed. This is a case where the operating system affects performance. Bad code that does not keep the L2 Cache full can destroy performance.

E.) Processor Bus - The processor bus is the data path between the processor and the L2 Cache. The faster this bus is the less time it takes to get data and instructions stored in the L2 Cache.

F.) System Bus - The system bus is the data path between the processor, main memory, and the PCI bus (defined below). The faster the system bus is the less time it takes to get data and instructions to or from main memory. The real work you buy a server for happens in main memory. For example the contents of the data packets you send and receive that comprise a file, print job, database search, etc... all end up in main memory where it is viewed, sent to the printer, and/or written to a storage device.

G.) Peripheral Component Interconnect (PCI) bus - The PCI bus gives the respective platforms the ability to expand. The bus supports the PCI card slots which typically hold the video display card, ethernet card, etc... Just because a peripheral is supported on the motherboard of the computer does not mean it is not PCI bus based. Both platforms put PCI bus based devices like ethernet, SCSI, and serial ports on internal PCI buses that are present on the respective motherboards. The proper PCI configuration can also have a dramatic affect on performance. This is because the data ultimately ends up on the PCI bus while moving between main memory and the various input/output (I/O) peripherals (Ethernet, SCSI, serial port, etc...). PCI buses are either 33 MHz or 66MHz and are either 32 bit or 64 bit. A 33 MHz 32 bit PCI bus can move a theoretical maximum of 132 MBytes per second. In an example where you support only one 100 Base-T Ethernet network, which can move at most 13 MBytes per second, you do not need to purchase more computer than necessary.

H.) Direct Memory Access (DMA) and Interrupts - DMA is the ability for a peripheral to move data into main memory with very little or no intervention by the main processor. In other words, the ability to move data without consuming precious processor clock cycles. An interrupt to a processor is a signal that tells the processor it must divert its capacity to the process that caused the interrupt. The combination of these two dramatically affects overall system performance. If the platform has limited interrupt capacity and limited DMA channels, it limits the user's ability to add peripherals (and subsequently the number of simultaneous users). If the processor is spending its time handling all processes without the support of DMA, all server users suffer. The Power Mac platform does not have the interrupt and DMA limitations of many Intel solutions.

I.) Small Computer System Interface (SCSI) bus - SCSI is the standard for secondary storage devices like hard disk drives, CD-ROM drives, and removable data technologies (Zip drives, Jaz drives, magneto optical drives, and DAT drives). There are various implementations (SCSI-1, SCSI-2, and SCSI-3). All the user needs to know is what the sustained data throughput is of both the SCSI bus implementation on the computer and of the storage device purchased. SCSI-3 systems can support up to 40 MBytes per second data throughput. Most hard disk drives cannot deliver that performance or require special configuration to achieve said performance.

By understanding the relationships between the above elements, it is a simple task to define if a particular server can handle a certain number of users efficiently. Lets look a the differences in the two class of processors with these issues in mind then look at two roughly equivalent servers.

The following table compares four processors. The two Pentium Pro processors differ by their L2 Cache size. The 1 MByte L2 Cache version of the Pentium Pro is specifically for server applications because of its impact on performance. However, it was just announced this month (August 1997). The 300 MHz Pentium II is also a new offering and represents the highest performing processor Intel currently offers.

Processor Element	Pentium Pro	Pentium Pro	Pentium II	PowerPC 604e	Note
Processor Speed (MHz)	200	200	300	350	
L1 Data Cache Size (KBytes)	8	8	16	32	
L1 Instruction Cache Size (KBytes)	8	8	16	32	
L1 Cache Access Speed (MHz)	200	200	300	350	
Maximum Supported L2 Cache (KBytes)	256	1024	512	1,024	1
Processor Bus Speed (MHz)	150	150	150	100	2
System Bus Speed (MHz)	66	66	66	50	3
Data and Address Bus Interface (Bits)	64	64	64	64	
Instructions per clock cycle	NA	NA	NA	4	4
SPECint95	8.2	8.66	11.7	14.6	5
SPECfp95	6.21	6.8	6.79	9	5
Manufacturing Technology (microns)	0.35	0.35	0.35	0.25	6
Die Size	552 mils/side	552 mils/side	560 mils/side	47 sq. mm	7
Power Consumption, Average (Watts)	28	35	42	8	
Millions of Instructions Per Second	NA	NA	NA	629	8
List Price (August 1997)	$707	$2,675	$1,981	$695	9

Processor Comparison Notes

Note 1 - The Pentium Pro now comes in three L2 Cache configurations (256 KBytes, 512 KBytes, and 1 MByte). This processor is the most popular for small to medium sized Windows NT 4.0 servers. L2 Cache has little impact on the SPEC performance figures (see Note 5).

Note 2 - The current processor bus speed (the bus between the processor and L2 Cache) is slower on the PowerPC 604e by 50 MHz. However, the net affect of more registers, larger L1 Cache, faster processor speed, and large L2 Cache give the PowerPC its overall throughput advantage. Motorola has announced a “Backside L2 Cache” for its next generation processor that moves the processor bus speed to that of the processor clock speed. A number of vendors have already released product with this new PowerPC processor not shown.

Note 3 - The current Workgroup Server 9650/350 has a 50 MHz system bus (the bus between the processor, main memory, and the PCI bus). This speed will increase in future releases giving the Workgroup Server an even greater performance advantage.

Note 4 - All PowerPC RISC operation codes (opcodes) execute at the same speed. The CISC opcodes of the Pentium processor operate at different speeds. Some opcodes execute in a single clock cycle and others at much higher rates. As stated earlier it typically takes more RISC opcodes to produce the equivalent results of a single CISC opcode. However, the PowerPC does out perform the Pentium at the same clock speed for both integer and floating point arithmetic. Motorola has conducted opcode usage analysis of all software that runs on its processors and has implemented CISC functionality for many of the most used opcodes. Byte Magazine's test results show that a PowerPC even out performs multimedia tasks when compared to a Pentium using Intel's Multimedia Extension (MMX) technology. MMX does not help server performance.

Note 5 - The Internet has numerous explanations of the SPECint95 (integer performance rating) and SPECfp95 (floating point performance rating). In the case of the values presented the author feels the values for the PowerPC 604e could be as much as 10% too high. The author could not find the SPECint95 or SPECfp95 ratings specifically for the currently selling implementation of the Workgroup Server 9650/350. Values provided by IBM and Motorola using reference hardware were used. Note that the values used for the Pentium processors were all provided by Intel complete with detailed information regarding how they were derived. The differences in performance reflected in section II are consistent with the performance differences presented above.

Note 6 - The manufacturing technology value in microns represents the width of conductive traces that comprise the transistors of the respective processor. Using the simple analogy that the less distance an electron has to travel the faster the processor is, explains the importance of this number. Motorola will be moving to .15 microns in 1998 supporting clock cycles hundreds of MHz faster than the current 350 MHz PowerPC 604e.

Note 7 - The PowerPC processor die is dramatically smaller than the Intel Pentium. Less transistors, less complexity (in comparison), less heat generation, and subsequently greater reliability. The Pentium flaw reports (and possible recalls) will continue due to the Pentium's end of life issues. Intel and HP are well into development of the next generation processor which will attempt to provide as much backwards compatibility to existing software as possible. All current Windows NT server owners will have to purchase new servers to take advantage of this new technology.

Note 8 - The rating of Millions of Instructions Per Second (MIPS) cannot be determined for the Pentium. For the Pentium, the results are totally dependent upon the mix of opcodes used.

Note 9 - The list prices of the various processors will change weekly. The two higher values represent new introductions. This is one of the reasons a 200 MHz Pentium Pro based Windows NT 4.0 solution was chosen to compare to the Workgroup Server 9650/350 in the next section.

V. Server Hardware Comparison

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To establish a reference point for comparison, an Intel Windows NT 4.0 server with a 20 client license was chosen. This system is hand assembled using a low cost ATX tower, ATX power supply, keyboard, mouse, and has a one year warranty. This represents a significant cost savings over a roughly equivalent high end Compaq Proliant 5000 (over $5,000 cheaper) while providing identical performance. The Workgroup Server 9650/350 is a single Apple Computer part number with ISG added memory. It also has a one year warranty. The 9650/350 comes bundled with a large quantity of software for the ISG sales price shown. Both systems include ISG's markup, but do not include a monitor, a data backup solution, the installation fee, support costs, or sales tax. Refer to the notes on the next page for a detailed summary of what you are really purchasing for the quoted prices.

Hardware Element	Windows NT 4.0 Server	Power Mac 9650 Server	Note
Processor	200 MHz Pentium Pro	350 MHz PowerPC 604e	1
Maximum Number of Processors	2	4	2
Motherboard	Intel PR440FX	Power Mac 9600	
Primary Memory Size	128 MBytes	128 MBytes	3
Maximum Primary Memory	512 MBytes	768 MBytes	4
Read Only Memory	0	4 MBytes	5
System Bus Speed	66 MHz	50 MHZ	
Level 2 Cache Size	256 KBytes	1 MByte	
Level 2 Cache Speed	150 MHz	100 MHz	
Floppy Drive	1	1	6
Hard Disk Drive	9 GByte	2 x 4 GByte	7
CD-ROM Drive	12x Speed	24x Speed	8
PCI Bus	1	2	9
PCI Bus Slots	4	6	10
PCI/ISA Bus Slots	1	0	10
10 Base-T Ethernet	0	1	11
10/100 Base-T Ethernet	1	1	11
External SCSI-1 Bus	0	1	12
Internal SCSI-2 Bus	1	1	12
Ultra/Wide SCSI-3 Bus	0	1	12
Apple Desktop Bus	0	1	13
PS/2 Keyboard Port	1	0	13
PS/2 Mouse Port	1	0	13
Universal Serial Bus Port	2	0	14
Serial Port	1	2	15
Parallel Port	1	0	16
Display Card	Diamond Stealth (2 MByte)	IMS Twin Turbo 128 (4 MByte)	17
MIDI Port	1	0	
Line In Audio Port	1	1	
Line Out Audio Port	1	1	
Mic In Port	1	1	
Enclosure	Tower	Tower	18
Number of Clients Supported	20	250	19
Keyboard	1	1	
Mouse	1	1	
ISG Sales Price	$5,937	$7,000	19

Server Hardware Comparison Notes

Note 1 - This may appear to be a very unfair comparison, 200 MHz versus 350 MHz, but the industry markets this class of Windows NT 4.0 server as the best value for the money. Consider that you will only see a 30% increase in overall performance for a 300% to 500% increase in initial purchase price by switching to the fastest possible Pentium processor. This is derived by looking at Compaq, Dell, and HP server prices. Therefore the author considers this choice as a best in class comparison between the two platforms. In this case, while supporting up to 250 clients, the Workgroup Server 9650/350 will provide greater processing power to each client and directly improve overall productivity.

Note 2 - The chosen Windows NT configuration can support a second Pentium Pro (same speed and cache size required). Third parties sell two and four processor PowerPC 604e upgrade cards which the 9650 supports. To upgrade the Windows NT server, just purchase another processor and put it in. The 9650 requires the old 350 MHz PowerPC 604e processor to be replaced completely with the two or four processor module. This is a cost disadvantage for the 9650 owner.

Note 3 - Both systems use the same 64 Bit 168 pin Dual Inline Memory Module (DIMM) based memory.

Note 4 - Other Windows NT 4.0 servers support more than the 512 MByte limitation of this configuration. The user will have to buy the next higher capacity motherboard or switch vendors if more memory is required.

Note 5 - The Power Macintosh computer comes with 4 MBytes of Read Only Memory (ROM). In the ROM are defined several thousand executable functions which define the Macintosh operating system, system drivers, and the look and feel of all of its applications. In comparison to Windows NT 4.0, which is all hard disk drive based, the Mac OS is dramatically less vulnerable to catastrophic system failure. A single corrupted byte in a system Dynamic Linked Library within Windows NT 4.0 can mean the total loss of data. While the Mac OS is still susceptible to similar failure, the data in the ROM cannot be corrupted. It is the ROM that gives the Mac OS its consistency. This is also why Mac OS based applications are typically half the size of their Windows NT equivalent and consume less system resources to function. The other advantage of this is disaster recovery - the 9650/350 server can be booted from just a CD-ROM (no boot floppy required), even if it has no hard disk drive.

Note 6 - The Workgroup Server floppy reads all Windows floppy disk formats as well as Macintosh. The Windows NT server can only read Windows formats. Considering that the 9650/350 can support Windows and Mac clients simultaneously, this is an advantage.

Note 7 - The Windows NT server and Workgroup Server have equivalently performing hard disk drives. The Windows NT server has an additional 1 GByte of capacity and if the new Windows NT file system called FAT2 is used, the NT server will be able to more efficiently store large numbers of very small files (4 KByte block size versus 32 KByte block size). No advantage is seen for the storage of large files. Apple Computer is now testing its file system replacement which solves this problem for the Workgroup Server.

Note 8 - The Workgroup Server CD-ROM provides the fastest CD-ROM drive on the market. For disaster recovery, network wide file access, software installations, and software upgrades this capability gives the Workgroup Server a serious performance advantage.

Note 9 - The Workgroup Server has a very powerful performance advantage by having two independent PCI buses. Due to the Direct Memory Access (DMA) capability of the Workgroup Server's peripheral controllers (ethernet, SCSI, and serial ports), multiple data streams can cause serious PCI bus contention. Bus contention is a significant cause of data throughput degradation in a server. Two independent PCI buses reduces this problem significantly.

Note 10 - Though the Workgroup Server does not support a 16 bit ISA card slot, it does have more PCI card slots with three residing on each of the two independent PCI buses. See Note 9 above.

Note 11 - The Workgroup Server comes with a 10 Base-T Ethernet connection on the motherboard, plus it comes with a 10/100 Base-T Ethernet PCI bus card. The Mac OS 8 now supports both networks simultaneously (multi-homing, multi-node, and IP Multicast).

Note 12 - The Workgroup server has 3 different SCSI buses. The external SCSI-1 port supports a sustained data rate of 5 MBytes per second and is ideal for Jaz, DAT, or CD-R devices. The internal SCSI-2 bus supports a sustained data rate of 10 MBytes per second and is used by the internal 24x speed CD-ROM. It also allows the addition of high capacity hard drives in the multiple drive bays the Workgroup Server tower supports. The third SCSI-3 bus supports ultra fast hard disk drives including the two 4 GByte drives that come with the Workgroup Server purchase. The Intel motherboard used only supports a single SCSI-2 bus for its 9 GBytes hard disk drive and 12x speed CD-ROM.

Note 13 - The Apple Desktop Bus (ADB) port on the Workgroup Server is a multiple device bus and supports its keyboard, mouse, and other input devices. The Window NT server provides a PS/2 port for the keyboard and PS/2 port for the mouse.

Note 14 - The Windows NT server has two Universal Serial Bus (USB) connectors which support up to 12 Mbps of data flow. USB devices are being developed by a large number of manufacturers and will become more available in the future. This is not currently supported by the Workgroup Server 9650/350.

Note 15 - The Workgroup Server has two high speed Geoport capable serial ports. The ports support up to 230 Kbps for normal operation, and up to 2 Mbps if the signal is externally clocked. For the new 128 Kbps Geoport ISDN modems no power supply is required - just plug it into the server. The Windows NT server has a single traditional 9 pin serial port.

Note 16 - The Workgroup Server does not support the use of a parallel port.

Note 17 - If the application for the Workgroup Server or Windows NT server is as a print server, the Workgroup Server has a very serious advantage. Using the 128 bit accelerated graphics card, in combination with an Apple Computer monitor and the new color synchronization software, a server user can color calibrate a printer or print job in short order. Otherwise, the accelerated graphics card on the Workgroup Server will be under utilized in a server environment..

Note 18 - The Workgroup Server tower enclosure is an award winning design that gives rapid access to all system components. It took the author of this document less than 20 minutes to add two hard disk drives, 128 MBytes of RAM, and two video display cards to his system. No tools were required to open the tower or swing out of the way the hinged power supply.

Note 19 - Power Mac computers with Mac OS 8 do not need to have client software installed, it is part of the Macintosh operating system. Also, the Workgroup Server 9650/350 part number used for this comparison allows up to 250 clients to be connected. To support the same number of clients by the Window NT 4.0 server would represent an extremely large increase in the initial cost. The Windows NT 4.0 server only comes with Windows NT 4.0 installed. The Workgroup Server 9650/350 offers a complete array of productivity software including the following:

- AppleShare IP 5.0
- COPSTalk
- Vicom Gateway with DHCP
- Claris Home Page
- AppleShare Client for Windows
- Server Manager
- LogDoor
- Claris Emailer

VI. Conclusion

Both technologies have matured rapidly over the past few years. The competition has forced Apple Computer, IBM, Intel, Microsoft, and Motorola to lower costs and increase performance across their respective product lines. It is obvious that the two platforms have reached a consensus regarding architecture. They now have similar cache, memory, PCI bus, and SCSI bus configurations. However, Apple Computer in concert with IBM and Motorola have created a processor that changes the value/performance equation. This document presents a large amount of objective evidence to support this. However, there are a number of subjective issues that influence the final evaluation. The below items are subjective only to the extent of how much, not if they are true or not. The Internet is a rich reference source and it is easy to find sufficient information of first hand experience to support the below:

• It takes less skill to maintain a Workgroup Server 9650/350 with Mac OS 8 and AppleShare IP 5.0 than a Windows NT 4.0 server.

• The Workgroup Server takes less labor hours to maintain than a Windows NT server..

• The Workgroup Server offers greater security to protect valuable corporate data than a Windows NT server.

• The Workgroup Server can recover from a system crash faster than a Windows NT server.

• Apple Computer produces the most reliable computers in the industry.

• Mac OS 8 is a more stable operating system than Windows NT 4.0.

If a computer scientist presented the theoretical advantages of preemptive multitasking and protected memory you would not consider Mac OS 8 superior to Windows NT 4.0. However the reality of the respective implementations clearly state otherwise. Mac OS 8 now has protected system memory space and separate application space. It also has a decade of 32 bit clean operation backing its implementation versus Microsoft's relatively new effort with Windows NT as its 32 bit operating system. The thread manager of Mac OS 8 gives the Workgroup Server equivalent multitasking capability to the multitasking capability of Windows NT. Using the more efficient and reliable code base of the Mac OS 8 in combination with the advantages of the Workgroup Server hardware, the solution delivers a much higher return on investment for the customer.